Observation of the Magnetization Dynamics in Artificial Spin-Ice Probed by Resonant Magnetic X-ray Photon Correlation Spectroscopy

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Artificial spin-ice systems (ASI) [1] are lithographically fabricated patterns of ensembles of magnetostatically interacting ferromagnetic nano-islands with a bistable single-domain behaviour of the magnetization. They can be arranged in geometries that mimic the magnetic frustration present in bulk spin-ice materials [2]. These Ising like macrospins then take the place of the atomic magnetism in the three dimensional equivalent bulk materials. These in turn are analogous to the proton disorder in water ice [3]. Describing systems that are out of equilibrium remains a significant challenge for condensed matter physics.

The excitement and interest in these systems stems from the ability to tune the interactions and to realise statistical mechanical vertex models in which the magnetic configuration can be imaged with such techniques as photoemission electron microscopy, PEEM [4] or magnetic force microscopy, MFM [5].

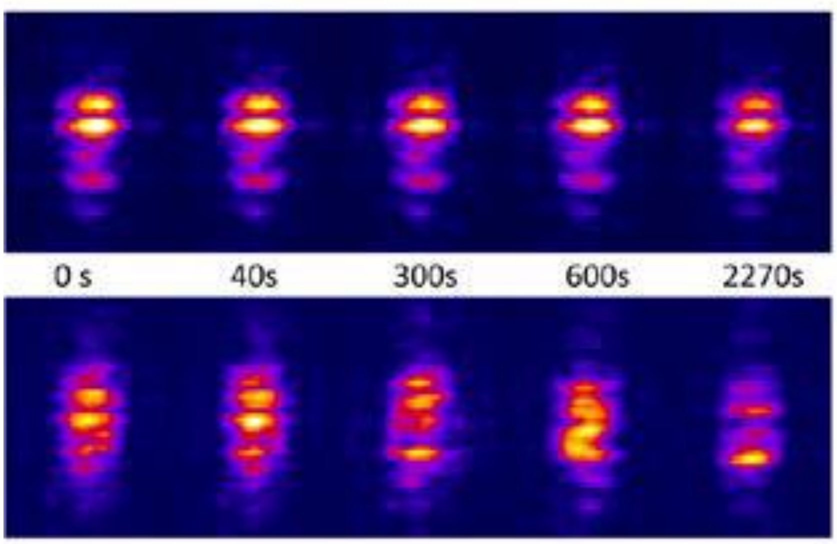

Fig.1: The time evolution of a frozen speckle (top) and a dynamic speckle (bottom).

Until recently, ASIs have been athermal due to the large shape anisotropy barrier that inhibits the flipping of a nanoisland’s magnetization. Within the last couple of years several groups have been able to realise thermal ice in a range of geometries [6,7].
Here we report on the magnetization dynamics exhibited in ASI systems by thermal excitations using resonant magnetic x-ray photon correlation spectroscopy (XPCS). This technique allows us to explore the time-correlations in the dynamics of ASI patterns formed by nano-islands that are too small to resolve with the aforementioned imaging techniques. The coherent illumination of a portion of the ASI array facilitates the observation of the evolution of the magnetic speckle in time. The speckle is imaged with a CCD camera and the time-time autocorrelation function of the images is calculated, from this a characteristic relaxation time for the magnetization dynamics is extracted at each temperature. We have studied the relaxation times of the magnetic fluctuations of the ASI samples at different temperatures and found that they are well described by a Vogel-Fulcher-Tammann law [8 and references therein], indicating glassy-type freezing of the system. This is unexpected for a system with a well-defined ground state [9].

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